EXPERIMENT #8: BINARY ARITHMETIC OPERATIONS

OBJECTIVES:

- Design and implement a circuit that performs basic binary arithmetic operations such as addition, subtraction, increment, and decrement.
- Use a multiplexer as a data selector.

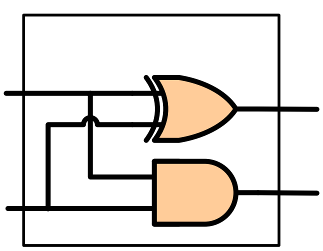
Equipment and ICs:

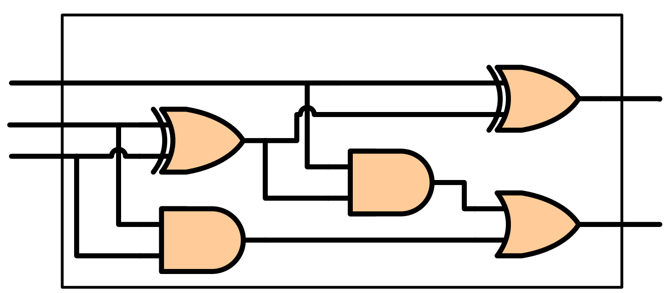
- Mini-Lab ML-2001 lab station
- 2 - IC 7493 4-bit ripple counter
- 2 - IC 7408 Quad 2-input AND gates
- 1 - IC 7404 Hex Inverter gates
- 2 - IC 7432 Quad 2-input OR gates
- 2 - IC 7483 4-bit Full Adder
- 1 - IC 7486 Quad 2-input XOR gates
- 2 - IC 74153 Dual 4 x 1 Multiplexer
- 8 extra LEDs

Introduction:

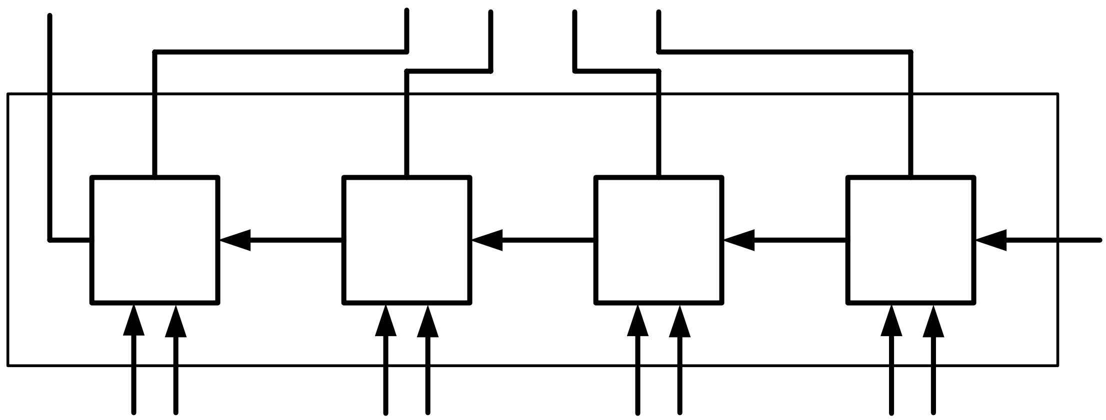
A full-adder is a very important digital circuit that can be used to perform all binary arithmetic operations such as addition, subtraction, multiplication, increment, decrement, etc.

A full-adder can be constructed using two half-adders. The half-adder (**HA**) and full-adder (**FA**) circuits constructed using XOR, AND, and OR gates are shown below:





A full-adder can be used to construct a 4-bit binary adder as shown below:



<u>Part 1: Binary Adder Circuits</u>

<u>Pre-lab Work:</u> (All Pre-lab work must be shown in the Pre-lab report)

1. Construct a 4-bit binary adder using four full-adders as shown in Figure 2 above.

2. Draw and simulate your circuit in LogicWorks. Include your LogicWorks drawing in the pre-lab report.

3. Verify the 4-bit binary adder operation for the following values:

A3	**A2**	**A1**	**A0**	**B3**	**B2**	**B1**	**B0**	**Sum**				**Carry out**
1	0	0	1	0	0	1	0					
0	1	1	0	1	0	1	1					
1	1	0	0	1	0	1	0					

<u>Lab Work:</u> (All Lab work must be shown in the Lab report)

1. Implement the full-adder circuit shown in Figure 1 on the proto-board.
   a. Connect inputs A, B, and C to three switches.
   b. Connect outputs S and C to one LED each.

2. Flip the switches On/Off, and check the output for all 8 possible combinations of inputs A, B, and C.

3. Tabulate output values for all inputs in a truth table.

Part 2: Binary Arithmetic Circuit

You will design and implement a circuit that performs binary operations on two 4-bit numbers as described in the table below:

Selection Code		Function	Function Description
0	**0**	**F = A + B**	**Add**
0	**1**	**F = A - B**	**Subtract**
1	**0**	**F = A + 1**	**Increment**
1	**1**	**F = A - 1**	**Decrement**

This circuit has two 4-bit values (**A** and **B**) and a 2-bit selector (**S**) as inputs. The circuit has two outputs: a 4-bit function result (**F**), and a carry-out ($\mathbf{C_{out}}$).

The circuit should be implemented using only a 4-bit adder (IC 7483), 4x1 multiplexers and one external gate. You may use inverters to generate the complement of an input.

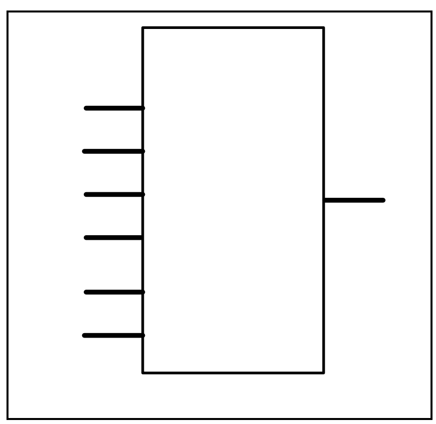
The increment and decrement operations are basically addition and subtraction operations, respectively. The increment operation adds 1 to a number (A+1) whereas the decrement operation subtracts 1 from a number (A-1).

The following describes how the other three operations namely – Subtraction, Increment, and Decrement can be performed using only the addition operation:

$$\mathbf{A_i \pm B_i = A_i + X_i + C_{in} \text{ where } C_{in} = \text{Carry In}}$$

$$\begin{aligned}
A_i + B_i &= A_i + X_i + 0 \quad \text{where } X_i = B_i \ \& \ C_{in} = 0 \\
A_i - B_i &= A_i + X_i + 1 \quad \text{where } X_i = B_i' \ \& \ C_{in} = 1 \\
A_i + 1 &= A_i + X_i + 1 \quad \text{where } X_i = 0 \ \& \ C_{in} = 1 \\
A_i - 1 &= A_i + X_i + 0 \quad \text{where } X_i = 1 \ \& \ C_{in} = 0
\end{aligned}$$

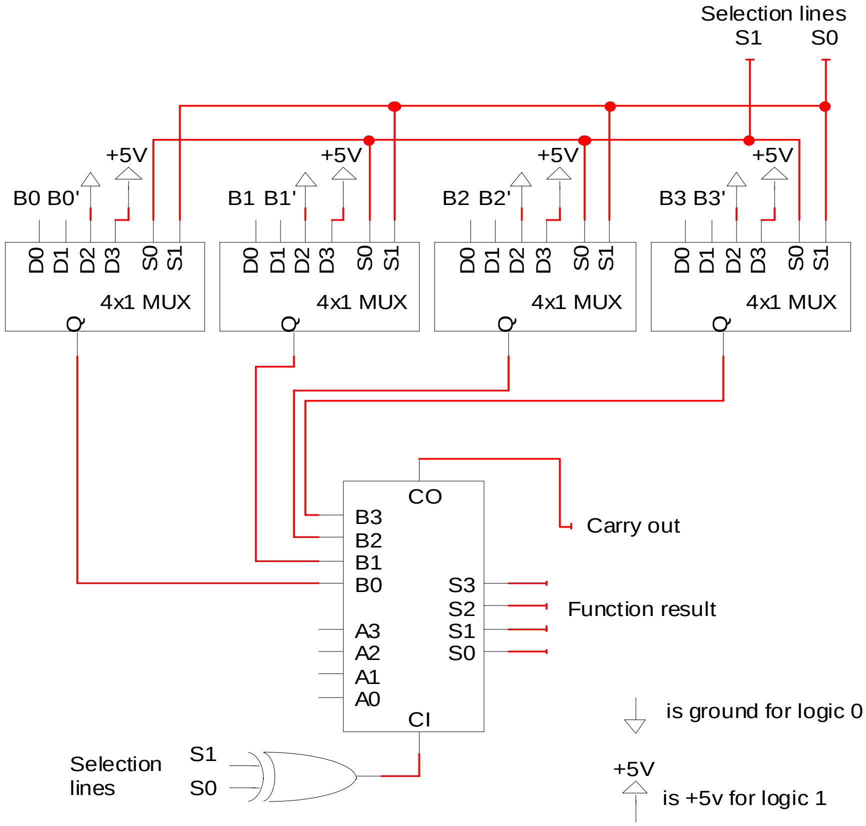
S1	S0	Function	X_i	$\mathbf{C_{in}}$
0	**0**	**Add**	$\mathbf{B_i}$	**0**
0	**1**	**Subtract**	$\mathbf{B_i'}$	**1**
1	**0**	**Increment**	**0**	**1**
1	**1**	**Decrement**	**1**	**0**



A multiplexer can be used to select one of four operations as shown in Figure 3. The output Xi of the multiplexer will be applied to input B of the 4-bit adder.

S1 and S0 are the selection inputs of the multiplexer. C_{in} can be generated using a single XOR gate.

The block diagram of the arithmetic circuit that performs the above operations is shown below:



Using only one 4-bit adder (IC 7483), we can perform all the above operations with the help of 4x1 multiplexers (IC 74153) and external gates.

Pre-lab Work:

1. Draw the complete logic diagram of the arithmetic circuit shown above in LogicWorks.
    a. Connect binary switches to all inputs $A_3A_2A_1A_0$, $B_3B_2B_1B_0$, and S1, S0.
    b. Use inverters to generate $\mathbf{B_i}$**'**.
    c. Connect the outputs Co and F to binary probes.

2. Verify all four arithmetic operations in LogicWorks.

3. Include your LogicWorks drawing in the pre-lab report.

Lab Work:

1. Implement the logic diagram of the arithmetic circuit on the proto-board using available ICs (7483, 73153 (2), 7404, 7486). Use your pre-lab LogicWorks diagram as a reference.
    a. Connect input A ($A_3A_2A_1A_0$) to four DIP switches and input B ($B_3B_2B_1B_0$) to the other four DIP switches.
    b. Connect two selection lines S_1 and S_0 to one SPDT switch each.
    c. Connect the output F to four LEDs or indicator lamps.
    d. Connect output Co to one indicator lamp.

2. Toggle switches connected to S_1 and S_0 to select one of the four operations as shown in the table below:

Selection Code		Function
0	**0**	**F = A + B**
0	**1**	**F = A - B**
1	**0**	**F = A + 1**
1	**1**	**F = A - 1**

3. Verify all the four operations of the arithmetic circuit by applying several sets of inputs A and B to the circuit.

4. Demonstrate the operation of your circuit to your lab instructor.

5. Record your results and observations for the lab report.